A Systematic Approach to Imaging of Three-Column Fractures in the Ankylosed Spine

Hannah A. Levy[1], Zachariah William Pinter[2], Elizabeth Wellings[1], Rachel Leigh Honig[1], Sandra Hobson, Ahmad Nassr, Mohamad Bydon[1], Arjun Sebastian, Benjamin D Elder[1], Brett Freedman[1]
[1]Mayo Clinic, [2]Mayo Grad School of Medicine

INTRODUCTION: The increased risk of spinal fractures in patients with ankylosing spinal disorders (ASD) following trauma has been well studied, though there is not a standardized imaging protocol and variation in care may occur depending on healthcare setting. The purpose of the present study was to report the experience across a healthcare system and provide evidence for a systematic approach to the ankylosed spine following trauma.

METHODS:

We identified 138 patients with ASD including ankylosing spondylitis (AS) or diffuse idiopathic skeletal hyperostosis (DISH) who sustained trauma resulting in 153 unstable 3-column fractures throughout the cervical, thoracic, and/or lumbar spine from 1999-2020. The primary physiologic outcome of interest was the sensitivity of XR, CT and MRI imaging and radiology reports for the identification of 3-column injuries. Functional outcome measures including ambulatory status and neurologic status were correlated with any delay in presentation, diagnosis, or treatment. Demographics, comorbidities, injury data, and site of initial presentation were identified for each case. Location of initial presentation was categorized as a primary care center (PCC, Level 2 ER or below) or a tertiary referral center (TRC, Level 1 trauma center). Each imaging modality (XR, CT, and MRI) was reviewed individually by board-certified orthopaedic and neurologic surgeons for the presence of 3-column injuries. Sensitivity of each imaging modality was assessed for its ability to detect different concerning findings including presence of fracture, ankylosis, cord compression, and/or epidural hematoma. These results were compared based on site of initial presentation (PCC vs. TRC) and its impact on delay in presentation, diagnosis, and treatment.

RESULTS: A cohort of 138 ASD patients with 153 fractures was identified; 56% with ankylosing spondylitis, 29% with diffuse idiopathic skeletal hyperostosis, and 15% with both. The majority of injuries occurred in the thoracic spine (51%) following a ground level fall (66%). Some 39% initially presented to the tertiary referral center (TRC), while 61% presented to the primary care centers (PCC). There was an increased risk of a false-negative CT reading (11% vs. 2%; RR=5.14; p=0.03) when performed at a PCC compared to a TRC. Conversely, MRI had a 0% false-negative rate. The sensitivity to detect a 3-column fracture was 0% for X-rays and 45% for CT. There was a significant difference in diagnostic delay between presentation sites (p=0.03).

DISCUSSION AND CONCLUSION: This study highlights the rate of false-negative imaging with X-rays and CT imaging alone, particularly when patients present to a PCC. MRI imaging demonstrated the highest accuracy in detecting fractures in patients with ASD following trauma.

Table 1: Patient demographics (n=153 fractures).

Male Gender	126 (82%)
Mean Age at Presentation (years)	75±12
Mean BMI (kg/m²)	33±7
Tobacco Use	64 (42%)
Diabetes	68 (44%)

Table 2: Injury Specific Data (n=153 fractures).

Ankylosing Disease	
AS	85 (56%)
DISH	45 (29%)
AS+DISH	23 (15%)
Injury Level	
Thoracic	77 (51%)
Cervical	35 (23%)
Thoracolumbar	30 (20%)
Lumbar	8 (5%)
Cervicothoracic	1 (1%)
Mechanism of Injury	
Ground level fall	101 (66%)
Motor vehicle collision/High energy	29 (19%)
Fall from height	20 (13%)
Site of Initial Presentation	
PCC	93 (61%)
TRC	60 (39%)
Surgical Intervention	113 (74%)

Table 3: Comparison of imaging modalities.

		Overall	TRC	PCC	*P-value	§Relative Risk
XRay (n=64)	A. States "3-column fracture" (True Positive)	0 (0%)	0 (0%)	0 (0%)	N/A	N/A
	B. States "fracture"	23 (37%)	11 (38%)	12 (35%)	1.00	1.04 (0.71-1.52)
	C. Equivocal statement without explicit diagnosis	14 (22%)	6 (21%)	8 (23%)	1.00	0.98 (0.75-1.28)
	D. States "negative for fracture"	15 (26%)	8 (28%)	7 (24%)	1.00	0.88 (0.37-2.10)
	E. No mention of "fracture" in report	12 (21%)	5 (17%)	7 (25%)	0.53	1.45 (0.52-4.03)
	F. Combined False-negative (D+E) (False-negative)	27 (43%)	13 (45%)	14 (41%)	0.80	0.92 (0.52-1.62)
	G. Mention of ankylosis present	22 (39%)	13 (48%)	9 (30%)	0.18	1.35 (0.88-2.08)
CT Impression Reading (n=153)	A. States "3-column fracture" (True Positive)	47 (39%)	32 (50%)	15 (27%)	0.01	1.45 (1.09-1.96)
	B. States "fracture"	108 (89%)	63 (97%)	45 (80%)	0.006	6.38 (1.48-27.59)
	C. Equivocal statement without explicit diagnosis	38 (32%)	20 (31%)	18 (33%)	0.84	0.96 (075-1.23)
	D. States "negative for fracture"	3 (2%)	0 (0%)	3 (5%)	0.10	N/A
	E. No mention of "fracture" in report	4 (3%)	0 (0%)	4 (7%)	0.04	N/A
	F. Combined False-negative (D+E) (False-negative)	7 (6%)	0 (0%)	7 (13%)	0.004	N/A
	G. Mention of ankylosis present	52 (50%)	34 (60%)	18 (38%)	0.03	1.55 (1.05-2.27)
CT All Findings (n=153)	A. States "3-column fracture" (True Positive)	67 (45%)	43 (48%)	24 (40%)	0.40	1.15 (0.86-1.53)
	B. States "fracture"	138 (90%)	87 (96%)	51 (82%)	0.01	4.04 (1.35-12.10)
	C. Equivocal statement without explicit diagnosis	6 (4%)	4 (4%)	2 (3%)	1.00	1.01 (0.95-1.08)
	D. States "negative for fracture"	2 (1%)	0 (0%)	2 (3%)	0.16	N/A
	E. No mention of "fracture" in report	7 (5%)	2 (2%)	5 (8%)	0.12	3.67 (0.74-18.32)
	F. Combined False-negative (D+E) (False-negative)	9 (6%)	2 (2%)	7 (11%)	0.03	5.14 (1.10-23.91)
	G. Mention of ankylosis present	90 (60%)	59 (66%)	31 (53%)	0.13	1.38 (0.93-2.04)
MRI (n=79)	A. States "3-column fracture" (True Positive)	54 (68%)	50 (69%)	4 (57%)	0.67	1.40 (0.56-3.53)
	B. States "fracture"	78 (99%)	71 (99%)	7 (100%)	1.00	0
	C. Equivocal statement without explicit diagnosis	1 (1%)	1 (1%)	0 (0%)	1.00	1.02 (0.99-1.05)
	D. States "negative for fracture"	0 (0%)	0 (0%)	0 (0%)	N/A	N/A
	E. No mention of "fracture" in report	0 (0%)	0 (0%)	0 (0%)	N/A	N/A
	F. Combined False-negative (D+E) (False-negative)	0 (0%)	0 (0%)	0 (0%)	N/A	N/A
	G. Mention of ankylosis present	48 (70%)	42 (68%)	6 (86%)	0.43	0.44 (0.07-2.82)

*P-value between locations; § Relative Risk of obtaining a false-negative finding at PCC compared to TRC. Relative risk considered N/A when one of the proportions is zero.

Table 4: Utilization of MRI following CT outcomes.

	Overall	TRC	PCC	*P-value	§Relative Risk
MRIs performed following positive CT for 3-column	52 (55%)	35 (56%)	17 (53%)	0.83	1.03 (0.67-1.67)
MRIs performed following negative CT for 3-column	27 (47%)	13 (46%)	14 (47%)	1.00	1.00 (0.62-1.61)
MRIs not performed following negative CT for 3-column	31 (53%)	15 (54%)	16 (53%)	1.00	1.00 (0.62-1.61)

*P-value between locations; § Relative Risk of not obtaining MRI following CT result at PCC compared to TRC.

Table 5: Time to presentation, time to diagnosis and delay and diagnosis.

	Overall	TRC	PCC	*P-value
Mean time to presentation (days)	4 (range, 0-68)	2 (0-23)	6 (0-68)	0.009
Mean time to diagnosis (days)	5 (range, 0-68)	2 (0-23)	7 (0-68)	0.002
Mean delay in diagnosis (days)	1 (range, 0-39)	0 (0-6)	2 (0-39)	0.03

*P-value between locations, PCC compared to TRC. Outliers excluded beyond 3 standard deviations (≥80 days).

Table 6: Survival and functional outcomes.

	Overall	TRC	PCC	*P-value	§Relative Risk
90-day mortality rate	15% (95% CI=10%-22%)	20% (95% CI=12%-32%)	13% (95% CI=8%-22%)	0.09	N/A
1-year survival	77% (95% CI = 69%-83%)	73% (95% CI = 60%-83%)	77% (95% CI = 67%-85%)	0.09	N/A
Neurologic sequelae	20 (14%)	11 (20%)	9 (10%)	0.14	0.52 (0.23-1.17)

P-value between locations; § Relative Risk of neurologic sequelae at PCC compared to TRC. No Relative Risk calculation applicable for survivorship analysis